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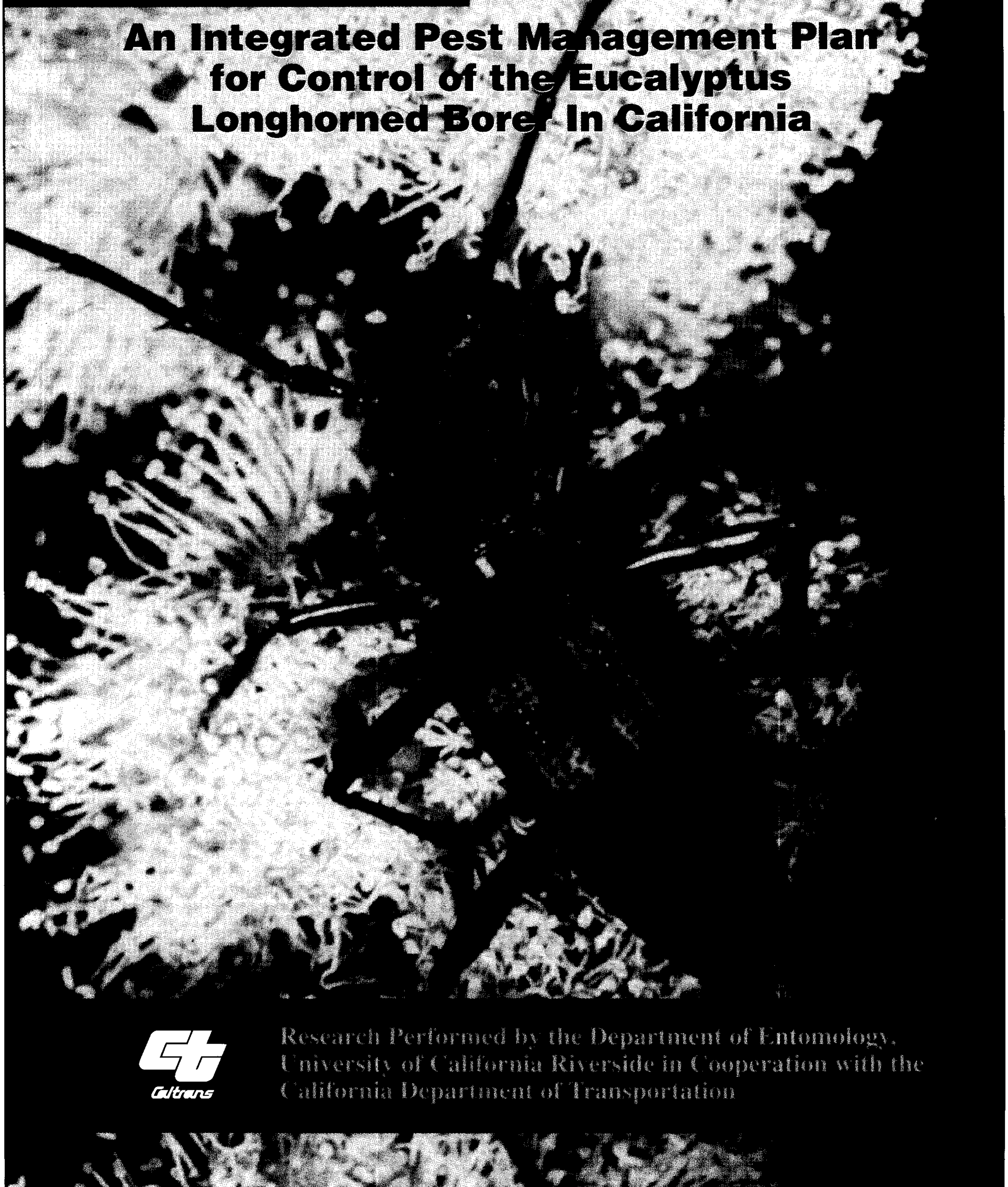
FINAL REPORT

An Integrated Pest Management Plan for Control of the Eucalyptus Longhorned Borer In California



Research Performed by the Department of Entomology, University of California Riverside in Cooperation with the California Department of Transportation

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16. Abstract

The research program sponsored by California Department of Transportation on the Eucalyptus longhorned borer has produced a multi-faceted and integrated pest management program for control of the insect. The basic biology of the insect in California, including the development time, number of generations, flight seasonality, and temperature thresholds, have led not only to a recognition that trees throughout the state are potentially susceptible, but also that silvicultural practices like timing of pruning, severity of pruning, and sanitation are critical for limiting risk of infestations. Tree stress, particularly water stress, has been identified as the key element leading to tree susceptibility and management practices (e.g. irrigation or mulching) have been developed to enhance tree resistance to the beetle. The most susceptible and most resistant commonly planted Eucalyptus species have been determined; E. saligna, E. globulus, E. nitens, E. viminalis, and E. diversicolor, are highly susceptible to Eucalyptus longhorned borer, while E. robusta, E. sideroxylon, E. camaldulensis, E. cladocalyx, E. citriodora and E. trabutii appear to be relatively resistant. It has also become clear that site conditions and tree maintenance are important contributors to species susceptibility or resistance. Our introduction and establishment of parasitic wasps offers a cost effective, safe, and permanent reduction in beetle populations. We have a continuing commitment to accomplish all the objectives we set out at the beginning of the research project. We feel that we have been very successful, and we have seen our integrated management program adopted by both public and private clientele throughout California.

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An Integrated Pest Management Plan for Control of the Eucalyptus Longhorned Borer in California

(DOTP-RD 177)

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Objective:

To develop and implement an integrated pest management program for control of eucalyptus longhorned borer through biological control, host tree resistance, cultural practices, chemical ecology, and sanitation.

List of Tasks:

a. Obtain natural enemies from Australia

b. Develop rearing procedures for eucalyptus longhorned borer

c. Develop rearing procedures for natural enemies

d. Rear large populations of natural enemies for release

e. Identify potential sites for release

f. Conduct releases of natural enemies

g. Evaluate establishment and effectiveness of natural enemies

h. Determine *Eucalyptus* species susceptibility to eucalyptus longhorned borer

i. Determine relationship among cultural practices and susceptibility to eucalyptus longhorned borer

j. Determine chemical composition of beetle attractants from susceptible eucalyptus trees

k. Prepare draft final report

l. Publish final report

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DISCLOSURE

Caltrans entered into a Research Technical Agreement (RTA-53Q348) with the University of California, Riverside to contribute to their Entomology Department's ongoing research project to find an integrated pest management control of the eucalyptus longhorned borer in California. Caltrans contributed $150,000 towards this effort. This enabled the Entomology Department to hire a post-doctoral staff entomologist to work full time on this project.

DISCLAIMER STATEMENT

INTRODUCTION

Eucalyptus trees were first planted in California around the turn of the century. The trees are native to Australia, but are adaptable to a wide range of Mediterranean environments. A large number of species of *Eucalyptus* were introduced into California, and the trees are valued for their vigor, tolerance of drought and poor soil conditions, and rapid growth rates. Although they have been in the state for many years, they have remained resistant to most of the native herbivores and diseases. Consequently, the trees usually have required little maintenance or management. These characteristics have made *Eucalyptus* a highly valued element in highway and urban landscape programs.

Until recently, *Eucalyptus* trees in California were relatively free of insect pests. This changed dramatically with the introduction of the Eucalyptus longhorned borer (*Phoracantha semipunctata*), a cerambycid beetle, into Southern California sometime before 1985 (see Scriven, Reeves and Luck; California Agriculture 1986). The insect is native to Australia, but is now found in all the major *Eucalyptus*-growing regions of the world. In Australia, the Eucalyptus longhorned borer rarely kills healthy trees, utilizing instead broken limbs, logging residues, burned trees, or highly stressed trees in landscapes. However, in almost all areas of the world with Mediterranean climates where this beetle has been introduced, it has rapidly become a pest, readily attacking and killing large numbers of *Eucalyptus* trees. This same pattern of beetle-caused tree mortality has been repeated in California.

Beetles are attracted to trees suffering from water stress, and unfortunately, many of the most common *Eucalyptus* species planted in California are from areas in Australia that have some precipitation throughout the year. Although capable of growing in areas that do not receive rainfall in the summer, many trees are moisture stressed during our dry summers. The problem is exacerbated in California for the same reasons that have made *Eucalyptus* so valuable. Because many *Eucalyptus* trees are grown in stressful environments with little supplemental irrigation, there are large numbers of susceptible *Eucalyptus* trees that are at risk of being killed by the beetle. The objective of our research on the *Phoracantha* - *Eucalyptus* system has been to develop an integrated management program to reduce risk of tree mortality.

BEETLE LIFE HISTORY AND DISTRIBUTION

Adult beetles commonly begin to emerge from infested trees or logs in late spring, and emergence can continue from individual brood logs for up to 16 weeks. Consequently, it appears that the beetles are flying throughout the warm season and there are no discrete generations. Males and females are attracted to suitable host material for oviposition by volatile chemical signals given off by fresh logs or susceptible trees. Mating occurs on the bark, and females lay eggs under loose bark or in crevices on the bark surface. During her life span, an adult female may lay several batches of up to 40 eggs in each batch. If given a source of pollen and nectar for food, such as found in *Eucalyptus* flowers, adult beetles can live more than 90 days.

Eggs hatch in 3-5 days. The first instar larvae mine very short distances in the outer bark layers before turning inward to mine at the inner bark-cambium-xylem interface. Larvae feed extensively in this tissue zone, effectively girdling the tree. Trees at this stage of infestation are characterized by thin, wilting or dry crowns with leaves remaining attached, cracked bark with packed larval excrement visible in the cracks, and often, the clearly audible rasping sound of chewing beetle larvae. At the end of the feeding period, the larvae excavate pupal chambers in the wood, packing the hole behind them with wood shavings and excrement or frass. Following pupation, the adult beetles emerge from the same hole by chewing through the plug of frass. A beetle generation can take about 8-10 weeks during the summer and longer during the winter. Survivorship from egg to adult under field conditions can range up to about 20%.

Phoracantha semipunctata was first detected in Orange County but populations are now continuously distributed throughout Southern California as far north as San Luis Obispo and Kern Counties. Well-established populations are killing trees in Alameda, Santa Clara and San Mateo Counties in the San Francisco Bay Area and infestations have been reported from Sacramento and Fresno. The disjunct statewide distributions may have resulted from movement of infested *Eucalyptus* firewood, but this has not been confirmed. Within the next decade, the beetle will probably be distributed throughout the range of *Eucalyptus* in the state; our studies indicate that the cooler temperatures in Central and Northern California will probably not adversely affect the beetle. We determined this by holding logs with developing beetles at temperatures as low as -5°C for up to 30 days and found that these temperatures did not affect survivorship but did delay adult emergence. Thus, it appears that *P. semipunctata* will survive even in the northernmost plantings of *Eucalyptus* in California.

INTEGRATED PEST MANAGEMENT OF THE EUCALYPTUS LONGHORNED BORER

Early work from both California and other regions of the world where *P. semipunctata* has become established demonstrated that insecticides are unsuitable for management of eucalyptus longhorned borer populations. Contact and systemic insecticide treatments are ineffective, costly, and environmentally inappropriate because of potential for drift, difficulty in achieving coverage on individual trees and on all trees across a broad geographic area, effects on beneficial or non-target organisms, and risk of exposure to human populations in urban environments. Consequently, attention has been directed towards maintaining environmental conditions that favor the tree to the disadvantage of the beetle.

Tree care and reducing stressful conditions

Dark brown gummy resin flowing from wounds in the bark of *Eucalyptus* trees may be a sign that a tree is under attack by the eucalyptus longhorned borer, but not always. Some species of *Eucalyptus* are heavy producers of gum and other species produce much less. It appears that healthy trees may produce larger amounts than stressed trees, but there does not appear to be a direct relationship between gum production and resistance to the beetle. In fact, it appears that moisture content of the spongy outer bark of *Eucalyptus* may be the mechanism of tree resistance to the beetle and a much more critical factor in determining whether or not a tree will be successfully colonized. Young larvae are killed as they attempt to penetrate through bark with a high moisture content, but readily mine through drier bark. Thus, trees under moisture stress are much more susceptible to attack. Ironically, trees that have grown in well-watered conditions but are suddenly subjected to water deficit seem to be at much greater risk than trees that have always grown under limited moisture conditions, because trees grown under more stressful conditions develop deeper root systems and utilize deep subsoil sources of moisture. Trees receiving frequent shallow irrigations, characteristic of urban landscape plantings, develop surface root systems and suffer acute water stress if irrigation is cut off, even for short periods. Consequently, these urban trees with the greatest economic value may be put at the greatest risk through improper water management.

In addition to water deficit, stresses associated with pruning may increase risk of infestation. Beetles are attracted to volatile chemicals associated with tree injury and may be attracted to freshly pruned trees as well as to the cut branch and leaf residue from pruning. However, like water stress, this type of stress can be managed. The beetles usually are actively searching for oviposition sites from May to October.

If tree trimming can be scheduled in months when beetles are not active, then the pruned trees will recover before beetles are present in large numbers, thereby minimizing the risk of tree death.

Selection of the right tree species

Selection of the right tree species for a specific location in the urban landscape is often a matter of aesthetics and availability. However, future pest problems, both insects and diseases, should be considered when a decision is made, because the tree will become a long-lived feature of the environment and will be costly to remove or replace. *Eucalyptus* have been extensively planted in California because they are non-deciduous, have few pest problems, and have required minimal maintenance. There are *Eucalyptus* species with aesthetic qualities to fit a tremendously broad range of site requirements. Some of these species, particularly *E. saligna, E. globulus, E. nitens, E. viminalis,* and *E. diversicolor*, are highly susceptible to Eucalyptus longhorned borer. In contrast, *E. robusta, E. sideroxylon, E. camaldulensis, E. cladocalyx*, *E. citriodora* and *E. trabutii* appear to be relatively resistant. There are, however, hundreds of species to choose from here and in Australia, but only a small fraction of these species have been evaluated for susceptibility to this insect. It is important to remember that even trees of a resistant species should be kept in vigorous condition. A tree of a susceptible species that is well cared for may be at less risk of infestation than a neglected tree of a resistant species.

Removal of sources of beetles through sanitation

Infested trees are a source of beetles for subsequent infestations. Infested trees that are cut down take on the appearance of firewood, but still contain many living larvae and pupae. Sanitation, the treatment or disposal of wood that contains larvae, pupae, or adult beetles waiting to emerge, is critical for reducing beetle numbers and limiting the number of trees that are killed each year. Any action must occur before the new generation of adult beetles emerges. Methods of treatment include burning, burying, chipping, or solarization (wrapping piles of cut wood in plastic exposed to direct sun for 10-12 weeks). Chipped *Eucalyptus* wood makes excellent mulch or biomass fuel and solarized wood can be safely stored for firewood.

Care must also be taken with cut uninfested wood. Until the wood dries below a critical level, it remains suitable and highly attractive for ovipositing beetles. Anything that can be done to speed the drying process (e.g. cutting and splitting the wood) will help reduce the length of time it can support beetle development. Also, removal of bark from freshly cut uninfested *Eucalyptus* logs prevents beetle infestation by removing the available food and increasing the rate of drying of the wood.

Chemical Ecology

Field observations and laboratory bioassays demonstrated that both sexes of adult beetles are attracted to volatiles produced by cut *Eucalyptus* wood and from *Eucalyptus* flowers. A reliable and reproducible wind tunnel bioassay was developed to test both entire extracts or fractions made from the extracts captured from wood or flowers. The attractancy of *Eucalyptus* flowers and cut wood was demonstrated and active extracts of both materials were developed. However, further work to isolate and identify the specific attractants proved very difficult. It appears that attraction depends on a complex blend of odors rather than a small number of compounds that can be easily isolated. Because of the difficulty of the problem of isolation and recombination of a complex mixture of volatile chemicals, this research area was reduced in priority relative to the others.

Biological Control

Eucalyptus longhorned borer is relatively uncommon in Australia and rarely kills trees in native stands. In Australia, all life stages of the borers are fed upon by a number of predacious and parasitic insects that are also native to the continent. Part of the explanation for the large number of *Eucalyptus* killed in areas around the world where the beetle has been introduced may be the absence of specific predators and parasites of the pest in those sites. We anticipate that our introduction of several species of parasites from Australia will permanently and safely reduce the borer population in California. The parasitic wasps that we have introduced are not a threat to human health or to the native fauna of the state. We have taken great care to demonstrate the specificity of the natural enemies for *P. semipunctata* and satisfied concerns over any threat to endangered species raised by the U. S. Department of the Interior, Fish and Wildlife Service.

The first step to establishing a successful biological control program was developing a mass rearing program for *P. semipunctata*. Because all the natural enemies must feed on the beetle, we needed to have large numbers of beetles in the proper life stage at the proper time to provide to the parasites as breeding material. Colonies of the eucalyptus longhorned borer were maintained in rearing logs held in greenhouse rooms. After completing their development in the rearing logs, adult beetles emerging from the logs were collected, sexed, and placed into mating/oviposition cages (five female and three male beetles in each 13 cm high x 13 cm diameter hardware cloth cylinder with 14.5 cm diameter petri dish top and bottom). Caged females oviposited batches of eggs on filter paper used to line the bottom petri plate. At peak production, we are capable of producing up to 5,000 eggs each day. These egg masses were monitored and as soon as the eggs hatched, the first instar larvae were collected. Fresh

Eucalyptus logs (two to four trees per week were required for continuous rearing of beetle and parasite colonies) were cut in the field, returned to the laboratory, the ends were coated with paraffin to limit desiccation, and the length and diameter measured. Calculation of the bark surface area determined the number of larvae that the log could optimally support. A sharp knife was used to cut a slit through the outer bark and the log was hand infested with the newly-hatched larvae. Once infested, the logs were placed in the greenhouse until needed by the parasite colonies or until the adults were ready to emerge.

Through the combined efforts of the Principal Investigators (foreign exploration and collection support provided by University of California) and Dr. Q. Wang at LaTrobe University, Melbourne, Victoria, Australia, an egg parasitoid (*Avetianella longoi*) and four species of larval parasitoids (*Syngaster lepidus, Callibracon capitator,* and two *Doryctes* species) were introduced and established in colonies at U.C. Riverside. To develop mass rearing techniques so that we could produce large numbers of parasites for release, we needed to determine key elements of the reproductive biology of the parasitic wasps. We determined that *Avetianella* females live 21 to 32 days (average of 24.5 days) and males live 15 to 30 days (average of 25.5 days). Females can lay 102 to 229 eggs (average 160 eggs) and 58% of the offspring are female. If given beetle egg masses of different ages, female parasites chose fresh eggs (66% parasitized), over 1-day-old eggs (27% parasitized), 2-day-old eggs (23% parasitized), or 3-day-old eggs (1.6% parasitized). If given egg masses of only one age, the females again used fresh eggs more frequently than older eggs (fresh, 37%; 1-day-old 19%; 2-day-old 13%; 3-day-old, 7% of those available). Further work demonstrated that newly emerged and mated females do not lay eggs immediately, but that there is a refractory/maturation period before oviposition begins.

Introduction of several parasites that specialize on different life stages of the beetle may increase the effectiveness of the biological control program. We have released or plan to release four species of braconid wasp parasites of Eucalyptus longhorned borer larvae. Adults of two *Doryctes* spp., *S. lepidus*, and *C. capitator* are attracted to infested *Eucalyptus* trees and use long egg-laying structures to drill through the bark and locate feeding beetle larvae. The female wasp parasites paralyze the developing larvae and lay one or more eggs on it. These eggs hatch and the developing parasite larvae feed on the borer larvae, eventually killing it. Development of the immature stages of these parasites takes approximately four to six weeks and the adult wasps tunnel out through the bark to emerge, mate, and search for new larval hosts. Studies of *S. lepidus* reproductive biology demonstrated that development time from egg to adult was about one month. If female *S. lepidus* oviposited in logs containing 2-week-old beetle larvae, predominantly small male wasps were produced. Logs containing 3 and 4-week-old beetle larvae produced medium-sized wasps of both sexes. Logs containing 5-week old beetle larvae produced only large female wasps. Consequently our mass rearing of this parasite uses a mix of logs, 67% containing 5-week old beetle larvae and 33% containing 3-week-old larvae, to optimize production of large mated *S. lepidus* females. The reproductive biology of *C. capitator* appears to be similar, but we have not been as successful in our rearing of this species as we have been with the others.

In contrast to *Syngaster* and *Callibracon* which lay a single egg on each larval host, both *Doryctes* species lay several eggs per host. Not only does this mean that there are more progeny produced for each beetle parasitized, but because the parasite is smaller in size than the other two species of larval parasites, smaller beetle larvae may be successfully parasitized. However, more parasites are produced on larger beetle larvae (10-15 wasps from 4-week-old larvae) than on smaller larvae (3 wasps from 2-week-old larvae).

We determined the characteristics for release sites (high beetle population density, accessibility, water, and security) and the most efficient release procedures to ensure the greatest probability for successful establishment. The procedure for releasing the egg parasitoid began with placing fresh eucalyptus logs at the site along with parasitized beetle eggs. The goal was to provide attractive logs to stimulate oviposition by wild *P. semipunctata* so that the parasites would have host eggs for their use as they emerged in the field. New logs and newly parasitized eggs were placed weekly at each site. Eucalyptus longhorned borer eggs that escaped parasitism hatched and colonized the logs. After an adequate time for larval development had elapsed, the logs were covered with fine net and adults of the larval parasitoid were released under the net to provide them with the opportunity and experience of parasitizing the beetle larvae in the logs before final release into the environment. The netting was removed from the pile of logs two days after the adult parasite releases. Additional logs containing parasitized larvae were placed on the pile. These parasites were allowed to emerge under field conditions and use the beetle hosts in the logs or fly to nearby infested eucalyptus trees.

We have conducted releases of *Avetianella* at nine sites in Southern and Northern California. Releases of *Avetianella* began with the release of 7,000 individuals in 1992 at five sites ([Fontana- San Bernardino Co., Rancho Santa Fe-San Diego Co., Will Rogers State Park-Los Angeles Co., U. C. San Diego-San Diego Co., and Stanford University-Santa Clara Co.). We released 52,830 *Avetianella* at nine sites in 1993 [Fontana- San Bernardino Co. (7,100), Rancho Santa Fe-San Diego Co. (6,500), Will Rogers State Park- Los Angeles Co. (8,250), Rustic Park-Los Angeles Co. (1,250), U. C. San Diego-San Diego Co. (5,500), U. C. Riverside- Riverside Co. (Campus site 4,800, Agricultural site 5,400), Riverside-Riverside Co. (8,500), and Stanford University-Santa Clara Co. (5,500)].

The egg parasite is highly effective at locating egg masses of *P. semipunctata* and very efficient at utilizing those egg masses. Of the egg masses we surveyed by Fall 1993, 71% were parasitized and 89% of the eggs in each mass were parasitized. Despite being very small in size, *Avetianella* is capable of long-distance dispersal. We found parasitization of naturally occurring eucalyptus borer egg masses at distances from 400m to more than 15km from each release location. We recovered established parasites at the San Bernardino, San Diego, and Riverside Co. release sites in surveys conducted during Spring and Summer 1994.

Initial releases of *S. lepidus* were made in 1991 at Rancho Santa Fe and U. C. San Diego in San Diego Co. A total of 532 *Doryctes* sp. B were made at Rancho Santa Fe, U. C. San Diego, Fontana, and Stanford University in 1992. A total of approximately 1000 *S. lepidus* were released in 1993 at six sites throughout the state. Although we recovered the parasite from trap logs placed at the release sites in 1993, no larval parasites were recovered in surveys of those locations in 1994. We are concentrating on release of larval parasites in 1994 with the expectation that release of larger numbers of individuals will result in establishment of these species.

TECHNOLOGY TRANSFER

Neither the natural enemies nor the tree management strategies will eradicate the Eucalyptus longhorned borer from California. Rather, the impact of the wasp parasitoids directly on survival of the beetle and the reduction in the number of highly susceptible host trees will result in populations of the borer and its natural enemies coexisting at lower, stable levels with reduced tree mortality. Although the prospects for reducing current rates of damage and tree mortality caused by the beetle appear to be very good, this also means that some stressed or highly susceptible *Eucalyptus* trees will still be killed by the beetle. It is critical that protection of valued urban tree species like *Eucalyptus* be viewed as a management system rather than a reliance on a single approach. No single control strategy is likely to be entirely effective. Instead, implementation of a combination of environmentally safe and complementary strategies that integrate proper tree management, sanitation, selection of resistant tree species for new plantings, and establishment of highly specific natural enemies for biological control holds the most promise for successfully managing this insect pest.

It is critical that tree maintenance personnel be trained to implement tree care practices that encourage vigorous growth and healthy trees. This includes planting *Eucalyptus* species in areas that are most suited for their growth requirements and providing irrigation where appropriate. If pruning is required, it should be conducted from November until March, when the beetles are not active, so the trees have time to recover from pruning stress before the flight season begins. Both infested and uninfested wood should be destroyed before beetles are able to complete their life cycles. Without an intensive rearing program, it could be difficult to either introduce the parasites to new areas or augment established populations of natural enemies. However, the parasite populations that we have established will provide the centers for natural distribution. The parasites are excellent at dispersing and locating infestations of the beetles. Their geographic distributions should soon overlap that of the beetle host and the population levels of the parasites will naturally increase to control any increase in the beetle populations. Biological control should be encouraged by limiting insecticide applications on *Eucalyptus* and through education of arborists as to the value of the parasites for maintaining the beetle populations at lower levels than they might be in their absence.

SUMMARY RECOMMENDATIONS AND IMPLEMENTATION

1. Trees under moisture stress are much more susceptible to attack than trees that receive adequate irrigation. It is important to maintain normal irrigation, particularly during the warm season, on landscape-grown eucalyptus trees that have always grown under those conditions because trees under acute moisture stress are attractive to the adult beetles.

2. As much as possible, limit stressful cultural practices (e.g. pruning) to the time of year when the beetles are least active–November through March. The trees will have an opportunity to recover from the stress before the beetles begin to fly in large numbers, thus reducing the risk of tree infestations.

3. Select *Eucalyptus* species for planting that are suited for the growing conditions, fit the aesthetic requirements for the site, and are resistant to the beetle. Resistant species include: *Eucalyptus robusta, E. sideroxylon, E. camaldulensis, E. cladocalyx, E. citriodora* and *E. trabutii.*

4. Avoid planting susceptible species, particularly in sites where supplemental care will be minimal. Susuceptible species include: *Eucalyptus saligna, E. globulus, E. nitens, E. viminalis,* and *E. diversicolor.*

5 Practice sanitation of eucalyptus wood. Uninfested wood that is cut (e.g. pruned branches or felled live trees) is suitable for beetle infestation until it dries out. Wood from infested trees remains suitable for the beetles to complete development even after it is cut. Thus, both infested and fresh uninfested wood must be destroyed. Burning, burying, or chipping is effective for both types of wood, solarization (covering logs with plastic and placing in direct sun for 10-12 weeks) eliminates beetles in infested wood, and stripping the bark from uninfested wood makes it unacceptable for beetle development.

6. If an infestation of eucalyptus longhorned borers is found, the status of the infestation should be determined (how many trees are currently infested and what is the stage of beetle development), infested wood removed, growing conditions improved as much as possible for the remaining trees, and natural enemies encouraged by not treating with insecticides. Once the egg parasites of the beetle are broadly established and with the proper experience, it may be possible for Caltrans workers to move parasitized egg masses into new infestations.

PROJECT SUMMARY

The research program sponsored by California Department of Transportation on the eucalyptus longhorned borer has produced a multi-faceted and integrated pest management program for control of the insect. The basic biology of the insect in California, including the development time, number of generations, flight seasonality, and temperature thresholds, have led not only to a recognition that trees throughout the state are potentially susceptible, but also that silvicultural practices like timing of pruning, severity of pruning, and sanitation are critical for limiting risk of infestations. Tree stress, particularly water stress, has been identified as the key element leading to tree susceptibility and management practices (e.g. irrigation or mulching) have been developed to enhance tree resistance to the beetle. The most susceptible and most resistant commonly planted *Eucalyptus* species have been determined, but it has also become clear that site conditions and tree maintenance are important contributors to species susceptibility or resistance. Our introduction and establishment of parasitic wasps offers a cost effective, safe, and permanent reduction in beetle populations. We have a continuing commitment to accomplish all the objectives we set out at the beginning of the research project. We feel that we have been very successful, and we have seen our integrated management program adopted by both public and private clientele throughout California. In fact, it has received international recognition as a pioneering effort for control of *P. semipunctata*, serving as a model for programs in both Portugal and South Africa, with further recent inquiries from Chile.

Publications Resulting from the Research Project

Hanks, L. M., T. D. Paine and J. G. Millar. 1991. Mechanisms of resistance in *Eucalyptus* against larvae of the eucalyptus longhorned borer (Coleoptera: Cerambycidae). Environ. Entomol. 20: 1583-1588.

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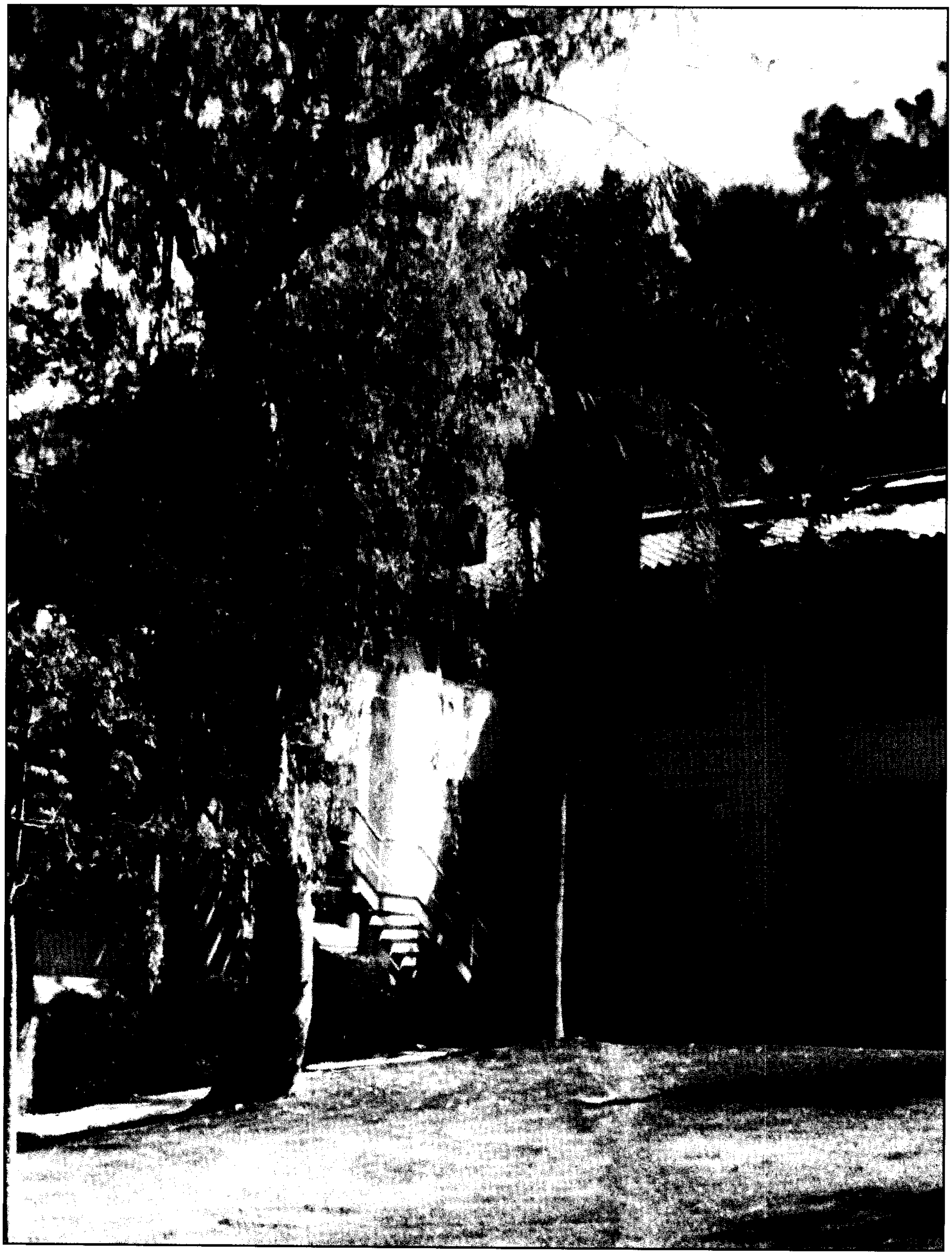
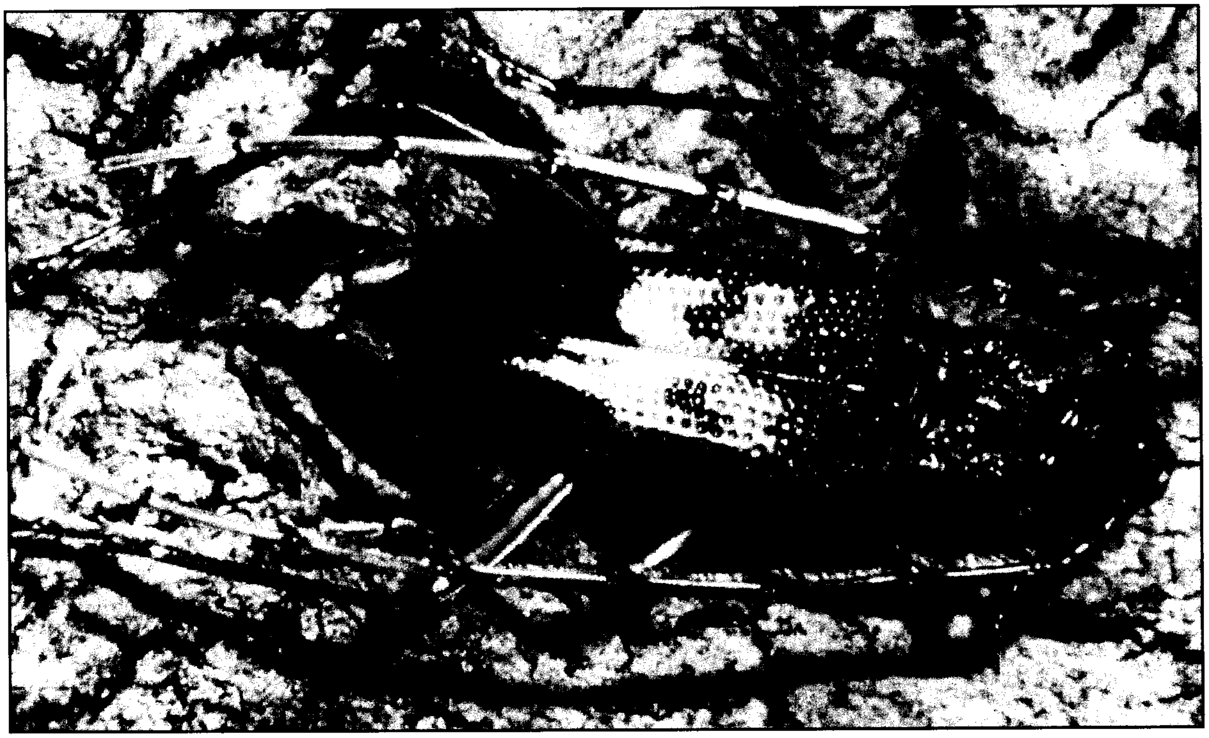
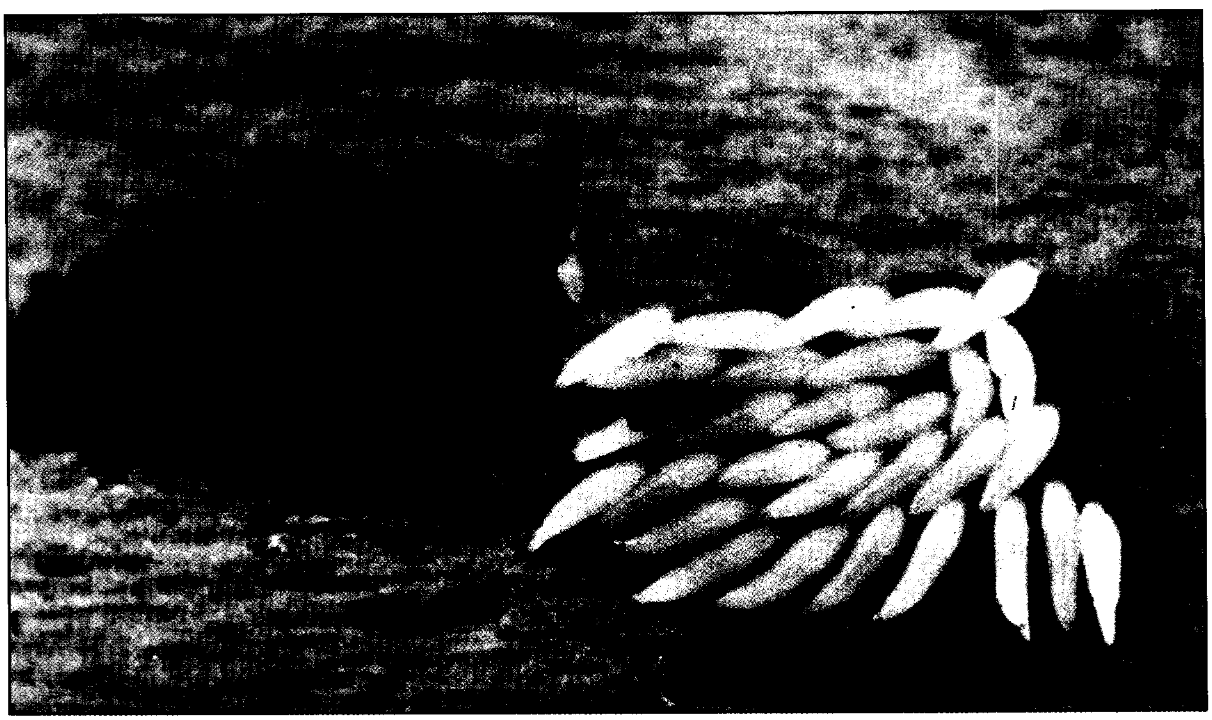


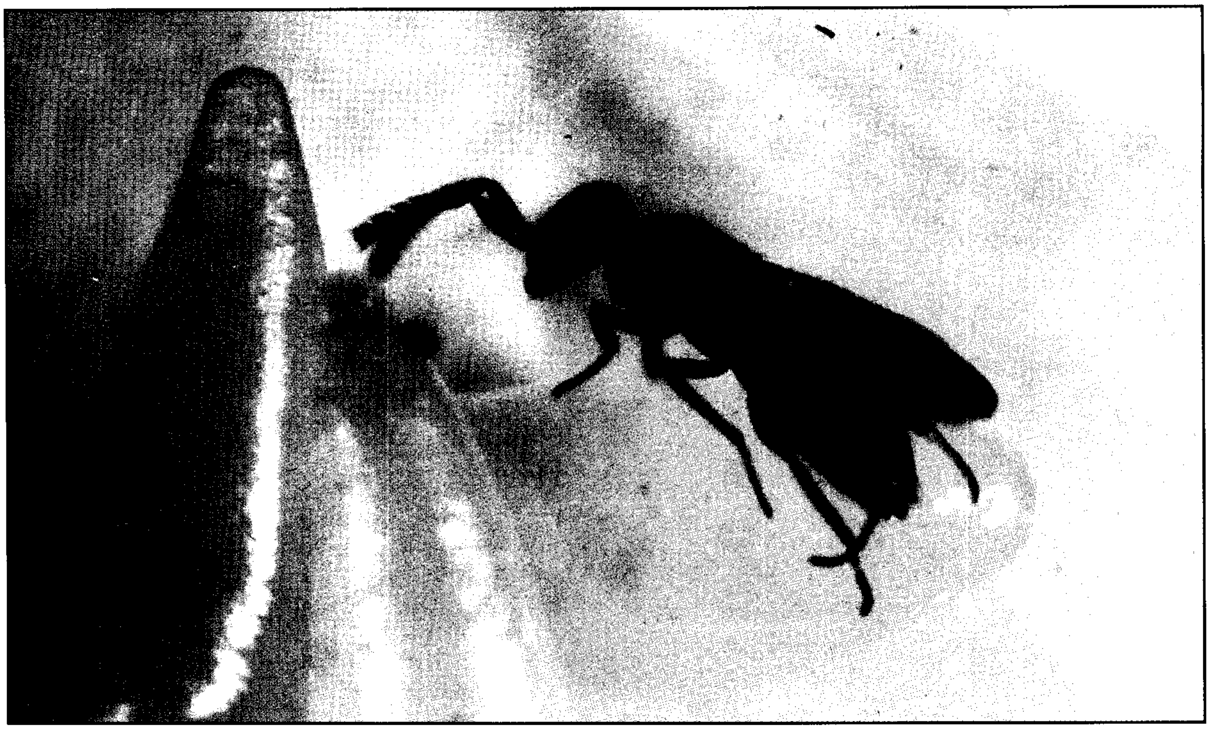
1. *Eucalyptus* tree killed by the eucalyptus longhorned borer.



2. Eucalyptus longhorned borer on bark of eucalyptus tree.

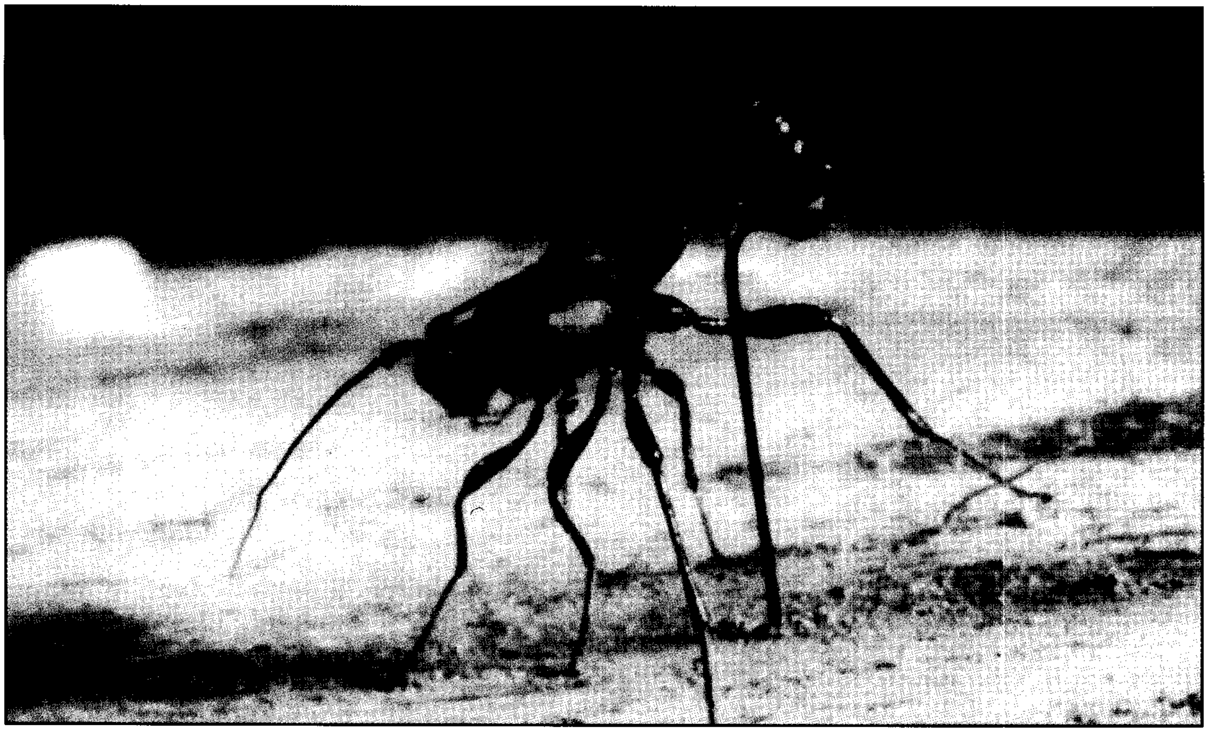


3. Borer females deposit their eggs under loose bark of eucalyptus.
Here bark has been peeled away to reveal borer eggs and two egg parasites (*Avetianella longoi*).

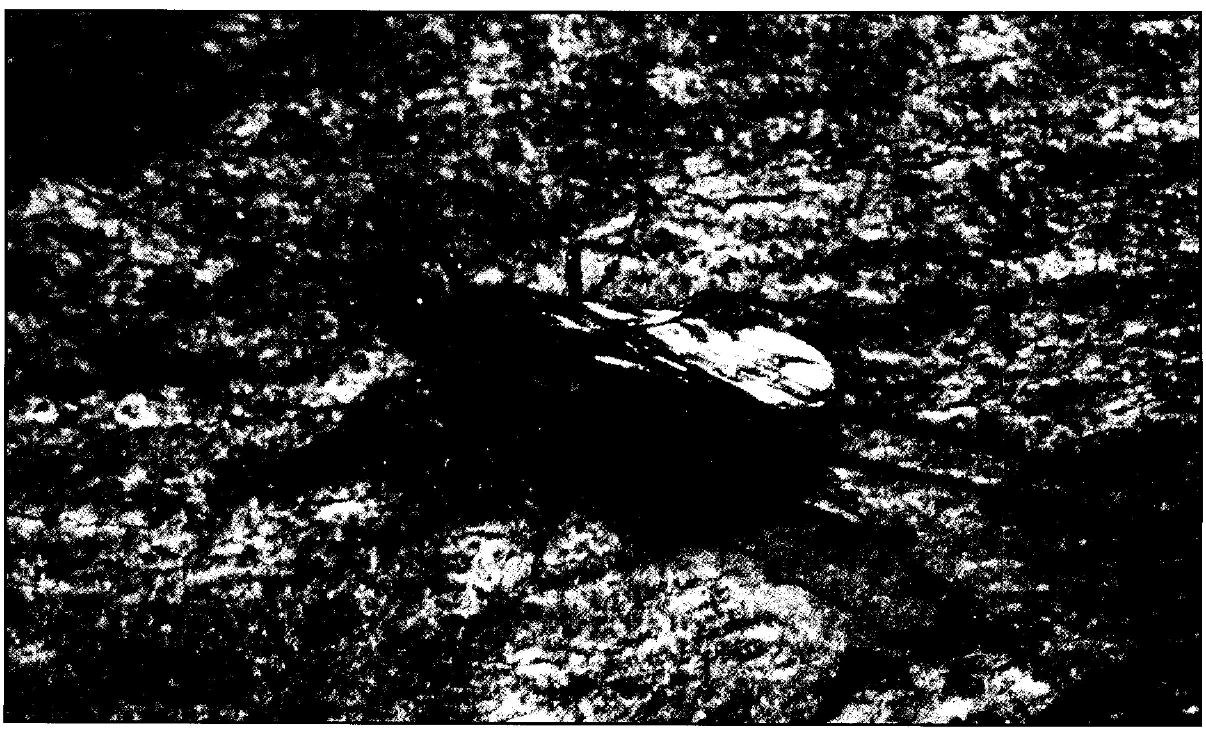


4. Egg parasite *Avetianella longoi* on borer eggs.

5. Eucalyptus longhorned borer larvae feeding on cambium under the bark.



6. Parasite *Syngaster lepidus* stinging borer larvae through the bark.



7. Parasite *Jarra phoracanthae* which also attacks larvae of the eucalyptus borer.